Are There Health Effects Associated with Coarse Particulate Matter?

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Science Question

- Particulate air pollution is broadly characterized and regulated in two principal size fractions: coarse and fine PM.
- Many epidemiology studies over the last decade have shown stronger associations mortality and exposure to fine PM) than to coarse PM.
- However, some recent studies have begun to show that coarse particles are also associated with increased morality and morbidity.
- The purpose of the research presented here was to more fully contrast and quantify health effects of coarse and fine PM.

Research Goals

- Determine the relative contribution of coarse particles to the total airborne PM.
- Identify the concentrations and components of coarse PM that increase cardiopulmonary mortality and morbidity
- Assess the role of biogenic materials on the health effects of coarse PM
- Identify populations that may be more susceptible to coarse PM exposure and determine the mechanisms of effect

Approach

- The approach tests the hypothesis that coarse PM increases cardio-pulmonary morbidity and mortality.
- This multidisciplinary program spans numerous scientific areas including exposure assessment and chemistry, epidemiology, pulmonary medicine, laboratory animal science, and cell and molecular biology.
- Epidemiology and exposure assessment studies provide information on type and concentrations of coarse PM and whether they are associated with specific health effects.
- Clinical experiments and panel studies provide more specific and detailed information on personal exposures and susceptibility factors which may drive the progression of disease during or after exposures.
- Cell and animal studies screen a large number of exposure scenarios for hazard identification and quantitative risk assessment purposes, and are used to test different biological mechanisms of the effects.

Monitoring and Collection

In contrast to fine PM which is mainly derived from combustion and smelting sources, coarse PM originates from abrasive practices such as milling and sand-blasting, re-dispersion of crustal and biogenic material, and natural processes like sea spray and pollen release.

Coarse PM levels are typically higher in the Southwestern US but are found at appreciable levels across the country **(Fig 1a).** The coarse fraction makes up more than 50% of the PM mass in the West Coast and between 30 and 40% on the Central U.S and East Coast **(Figure 1b).**

Elemental analysis of coarse particles shows enrichment of metals in the form of aluminum silicates and lower amounts of combustion byproducts such as organic and elemental carbon and sulfates **(Figure 1c).** Biogenic material comprises 10-20% of the mass of coarse PM and can have important biological activities including promotion of allergies and eliciting inflammatory responses **(Figure 1d).**

High volume cascade impactors are now available in order to collect large quantities of coarse, fine and ultrafine samples for comparative analysis and toxicity testing **(Figure 1e)**

Fig 1a PM10 concentrations in 2003 (second maximum 24 Hr)

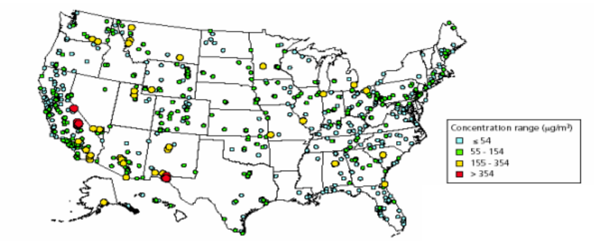


Fig 1b Percent of 2003 annual average PM mass by size

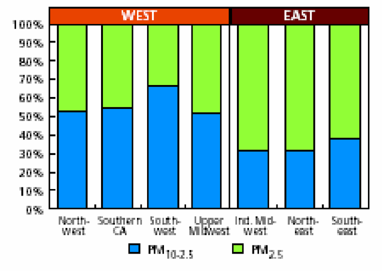


Fig 1c Distribution of elements in size fractionated PM

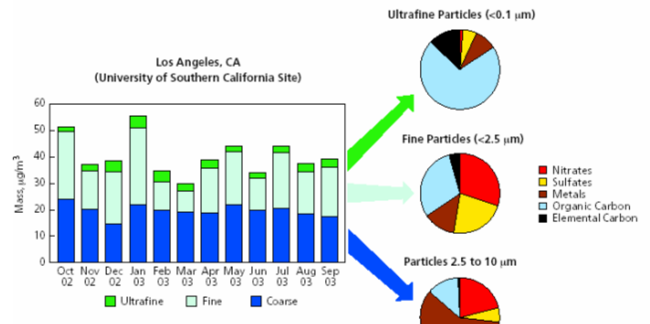


Fig 1d Particle Types in Coarse PM (SEMEDX)

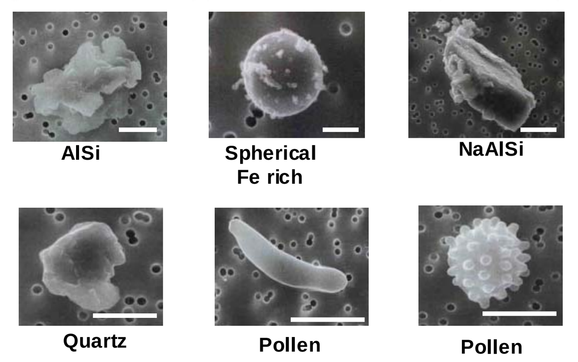
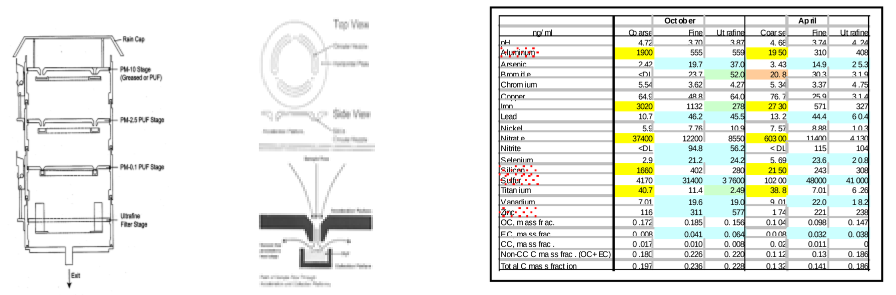


Fig 1e High Volume Cascade Impactor and Chemical Analysis



Epidemiology and Panel Studies

Most of the early epidemiology studies showed increased mortality following exposure to PM10 and these results were strengthened when the data were re-analyzed looking at PM2.5. Several recent studies examining the role of coarse particulates on mortality and morbidity however have also found effects. The Coachella valley study found associations between coarse particulate exposure and increased cardiovascular mortality **(Fig 2a).** Coarse particles have also been shown to increase the risk of having an asthma attack in children **(Fig 2b),** as well as the risk of having increased respiratory symptoms including cough, wheeze and shortness of breath **(Fig 2c).**

Fig 2a Relative risks for alternative measures of particulate matter (interquartile ranges); Coachella Valley, California.

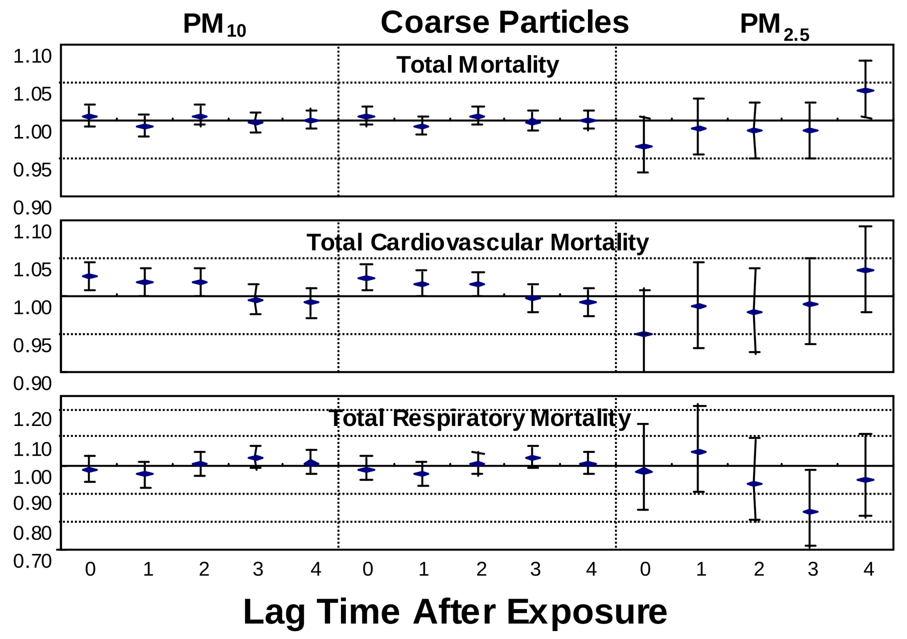


Fig 2b Estimated odds ratios for having a more serious asthma attack for short term within subject increases in (a) PM2.5 (10 µgm-3), (b) PM10 (10 µgm-3), and (c) CO (0.67 ppm)

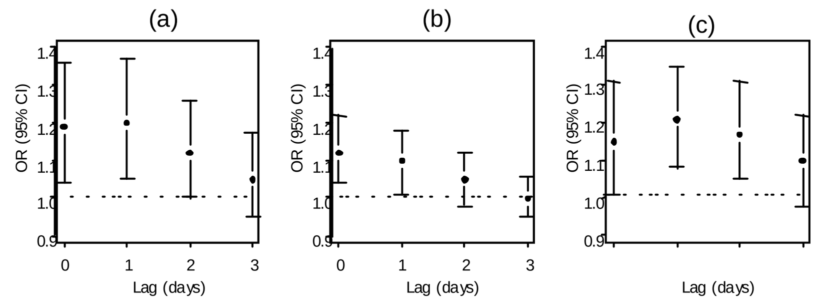


Fig 2c Children's respiratory symptoms: Estimated odds ratio and upper and lower confidence intervals for 10 µgm-3 increase in air pollutant

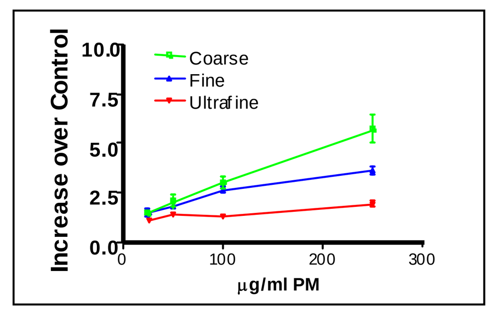
Symptom	Lag	PM_{10}	$PM_{2.5}$	Coarse fraction	PM_1
Wheeze	0	0.92(0.71,1.18)	0.55(0.26,1.19)	1.12(0.98,1.28)	0.51(0.14,1.83)
	1	0.89(0.64,1.24)	0.53(0.18,1.58)	0.98(0.78,1.24)	0.42(0.10,1.75)
	2	0.95(0.69,1.31)	0.55(0.19,1.64)	1.08(0.88,1.33)	0.40(0.12,1.32)
Breath	0	1.04(0.95,1.15)	1.13(0.86,1.48)	1.03(0.93,1.13)	1.08(0.80,1.45)
	1	1.04(0.95,1.15)	1.12(0.86,1.44)	1.05(0.97,1.14)	1.08(0.81,1.44)
	2	1.06(0.95,1.19)	1.10(0.82,1.48)	1.08(1.00,1.17)	1.05(0.77,1.43)
Cough	0	1.09(1.02,1.16)	1.17(0.98,1.40)	1.07(0.96,1.20)	1.20(1.00,1.44)
	1	1.08(1.02,1.14)	1.21(1.00,1.47)	1.06(1.02,1.10)	1.24(0.99.1.56)
	2	1.10(1.02,1.18)	1.18(0.99,1.42)	1.10(1.02,1.18)	1.21(1.02,1.43)

Mechanistic Studies

In order to identify biological active components in coarse PM and understand the mechanisms of effect, the materials can be collected, analyzed and incubated with a variety of different cell types *in vitro or* instilled into experimental animals. In addition to looking at standard toxicological effects such as pro-inflammatory cytokine release, the use of different strains of mice, or transfected cells with specific receptors, can provide information on the signaling pathways and effector responses. The Toll-like 4 receptor (Tlr-4) is of particular interest because this molecule is involved in recognizing bacterial lipopolysaccharide (LPS, endotoxin) which has strong biological activity, and is more abundant in the coarse fraction of PM. Coarse PM causes the release more IL8 and IL6 than fine or ultrafine particles collected from Chapel Hill, NC **(Figs 3a and c).** The IL8 effect is not blocked by LPS inhibitors indicating that Tlr4 is not involved in IL8 signaling while the converse is true for IL6 **(figs 3b and d).** The use of LPS responsive and non-responsive mice which differ in the functionality of Tlr-4 can further demonstrate whether LPS is an active component in PM and if the receptor is involved in pro-inflammatory signaling pathways. **Figure 3e** shows that PMN influx is equivalent in both susceptible and resistant mice while TNF-a production is clearly dependent on Tlr4 animals **(Fig 3f).**

Fig 3c, d Effect of size fractionated ambient PM on the release of IL8 by human bronchial epithelial cells with or without pre-treatment with the LPS inhibitors Polymixin B and E5531

3a



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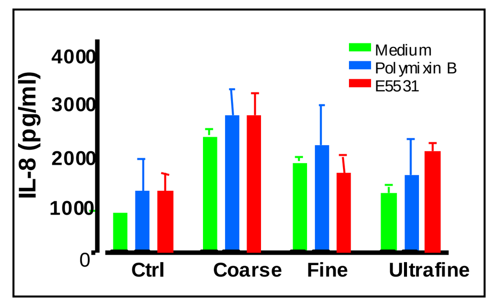
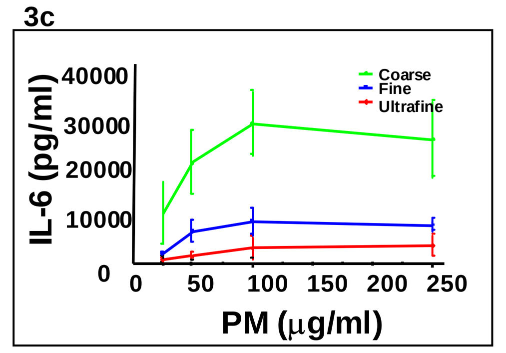


Fig 3c, d Effect of size fractionated ambient PM on the release of IL6 by human bronchial epithelial cells with or without pre-treatment with the LPS inhibitors Polymixin B and E5531

3c



3d

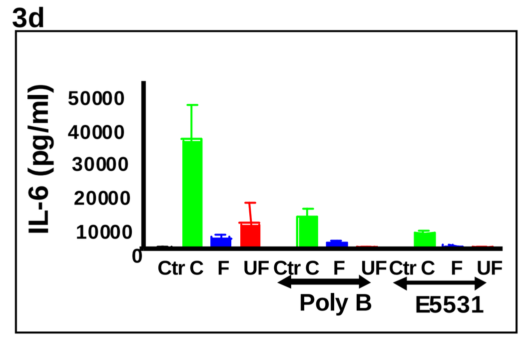
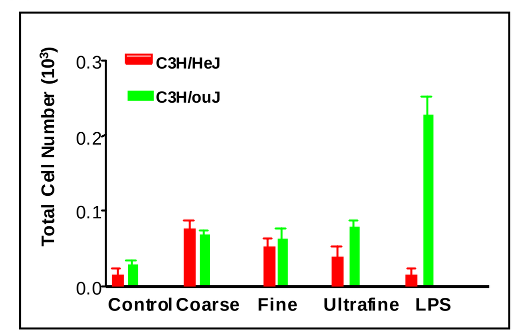
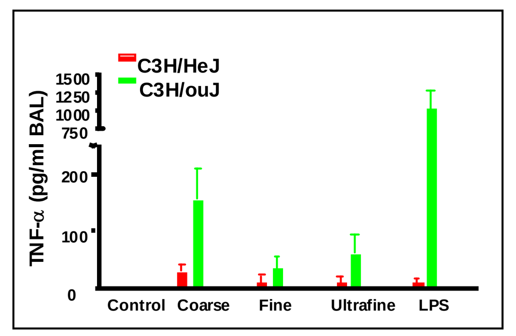


Fig 3e, f Effect of size fractionated ambient PM on PMN numbers and TNF-a release in LPS resistant (C3H/HeJ) and susceptible (C3H/OUJ) mice

3e



3f



Future Directions

Use of high volume cascade impactors to collect size fractionated particles from different geographical locations with different source profiles. Comparison of chemistry and health effects associated with each size fraction.

Wherever possible, collect samples above at locations where epidemiology and panel studies are being conducted.

Use concentrator technology to directly compare the effects of coarse, fine, and ultrafine PM in humans and animals in several locations.

Better understanding of the components found in coarse PM responsible for eliciting adverse health effects.

Impact and Outcomes

The OAR has listed as one of its highest priorities a better understanding of whether there are significant health effects associated with coarse PM. The work described in this poster will provide important information that can be used in this assessment.

The results of these studies also directly feed into criteria documents and standard setting for PM.

The fact that coarse PM is more prevalent in the West Coast has implications for the development of regional standards versus attainment of the national standard.

Coarse PM is mainly an outdoor air pollution problem and may disproportionately affect children who spend more time outdoors.

Since coarse PM tends to deposit higher in the respiratory tract, people with airways disease such as asthma may be especially susceptible to its effects.

Health and Exposure